AD-A187 957 TECHNICAL EVALUATION REPORT ON THE FLUID DYNAMICS PANEL SYMPOSIUM ON AERO..(U) ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT NEUILLY.. A W SMITH 1987 1/2

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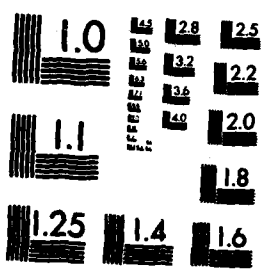

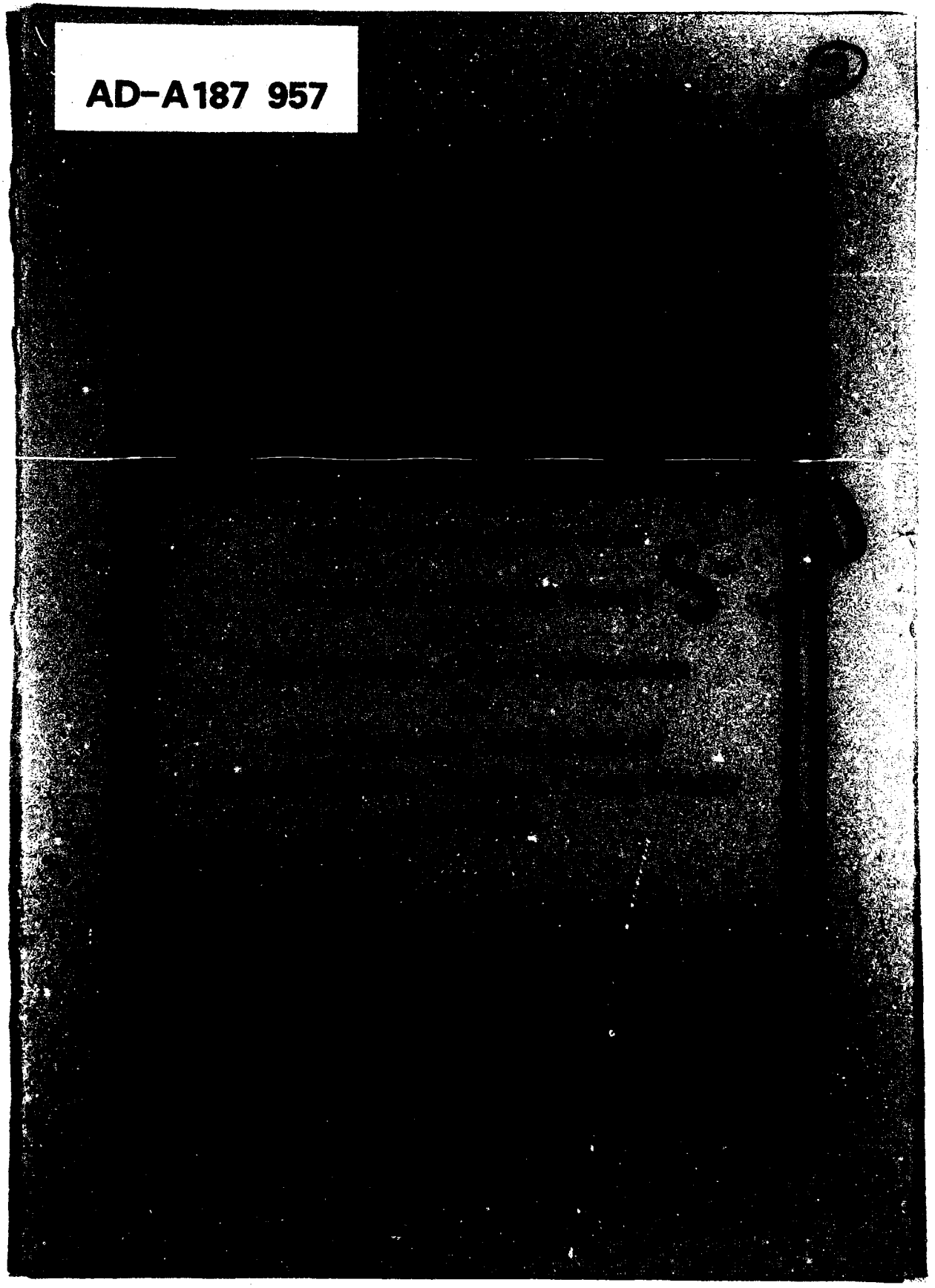

NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

AGARD Advisory Report No.225

TECHNICAL EVALUATION REPORT

on the

FLUID DYNAMICS PANEL SYMPOSIUM

on

AERODYNAMIC AND RELATED HYDRODYNAMIC STUDIES USING WATER FACILITIES

by

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SYMPOSIUM ON AERODYNAMIC AND RELATED HYDRODYNAMIC STUDIES USING WATER FACILITIES: TECHNICAL EVALUATION REPORT

by

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The meeting was held in Monterey, California, 20-23 October 1986; the papers presented are listed as references 1-33 at the end of this report.

This report is not only a "critique" of the actual meeting but also a commentary on the use of water facilities and flow visualization in general for aerodynamic purposes. I should remark that I am a somewhat prejudiced reviewer. When developing a new state of the art airplane I think that not only the usual low-speed and high-speed wind-tunnel models, aeroelastic models and possibly spin models should be tested but also a flow visualization model should be built and tested. The flow visualization model should be used to see if any unexpected kinds of flow occur - say a stray or unexpected vortex. I am not necessarily saying that the flow visualization model should be a water-tunnel model but experience seems to show that this kind can be considerably cheaper than a regular wind-tunnel model that is all fixed up for smoke or other kind of flow visualization. Besides, the visualization is often more vivid, as in Werle's pictures[14]. Just as many kinds of wind tunnel models really amount to insurance models because most of the time the desired performance is obtained, the flow visualization model is definitely an insurance model that is meant to protect the airplane's designers from unexpected and undesirable discoveries in the flight-test stage.

I am not unfamiliar personally with flow visualization. In 1953 I wanted to test a trapped vortex on a body of revolution. This is such an odd flow that it seemed impossible to make any progress without actually seeing the flow as a whole. Accordingly a small 16 ft. long towing tank was built[34]. Besides helping greatly on the original job it proved very useful on a number of airplane design problems. This tank was where the hydrogen-bubble technique was first developed[35].

A few years earlier I was worrying about peculiar and wild flows similar to many described at this meeting. I could get no help on them from any English book on aerodynamics or fluid mechanics. In fact the biggest help I got was from J.P. Den Hartog's book Mechanical Vibration. In trying to make progress on my problem I talked to Professor A. L. Klein of Caltech who also was a consultant to Douglas Aircraft. He characterized the study of unsteady, separated flows that do not follow a surface as "funny aerodynamics". This is a rather appropriate name for many of the flows described in this meeting. However because many of these "wild" flows have rather disastrous consequences perhaps it would be more appropriate to call them "sad" aerodynamics. While I have not made any thorough search, I am not aware of any meeting quite like this one. Of course there are many towing tank conferences but their purpose is different. Furthermore there is extensive literature on the flow visualization aspect in air[36]. Also, there is a book devoted to the subject[37], as well as the Proceedings of the International Symposium in Flow Visualization[38,39,40,41]. The meeting most similar to the present one that I know of was an A.S.M.E. Symposium on Flow Visualization in 1960[42], which I attended. It considered visualization in both water and air. In looking back to that time, which really is not so very long ago, I am certainly impressed by the advances that are clearly evident in the present symposium. At this earlier meeting there were no lasers or LDV. Computers and large scale data reduction methods were in their infancy; and fluorescence methods of flow visualization were just beginning. Moreover, the Fast Fourier Transform had not yet been introduced. I am sure that it is destined to see extensive use in the future, given the tremendous amount of data that can now be taken.

Flow visualization is especially useful when a problem is not really known or understood. With it, where a flow is going can at least be seen. Without it, in strange flows the situation is somewhat like a blind man with a cane trying to find the shape of or to identify a strange object. By tapping enough he can possibly identify it. Similarly by enough conventional testing with probes, hot wires, etc., an unknown flow might finally be mapped out. But think how much simpler and more positive it is to introduce some kind of flow visualization and then just look at it. The eye is a remarkable organ.

For the purpose of flow visualization this meeting is especially useful to people who are developing methods, as it brings them all together to learn of each other's work and to exchange ideas. Another useful function of the meeting is that it updates the audience and shows them what can be done at the very time of the meeting.

A meeting like this is more general than most AGARD meetings because it concerns an all encompassing technique. The usual AGARD meeting is on some specialized subject such as Fluid Mechanics of Aircraft Stalling. This meeting blankets all kinds of techniques, just making use of water as a working medium for test purposes. Large scale types of tests such as force tests may be considered, or flow visualization of many kinds may be made or tests of a very small component of the flow such as a Tollmien-Schlichting wave or the bottom of a boundary layer may be made. Thus the range of items treated is tremendously large. This is not a meeting for the specialist, at least the usual type of specialist. To realize further the basic generality of this meeting consider its equivalent using air. Then the title would be Aerodynamic and Related Hydrodynamic Studies Using Air Facilities. In air the term Air Facilities would mainly mean wind tunnels. Any meeting whose only qualification was that wind tunnels should be used certainly would be general.

The use of water instead of air offers much added versatility to tests. One fact is that water is chemically active and therefore many more means of flow visualization become possible than in air. Furthermore the motion is slow, making it possible to perform motions and measurements that are impossible in air flow, greatly simplifying LDV measurements, etc. For the same size model, water velocities that are needed to provide the same Reynolds number are roughly 1/6 of those in air, with both at room temperature. Furthermore, because of this velocity difference, towing a model in still air is quite uncommon, but towing a model in still water is very common. Two advantages of a towing tank are immediately apparent. First, the water, being still, the turbulence can be extremely low. Secondly, a wind tunnel has a test section that is only about one diameter long. Hence it is no good at all for investigating the decay of disturbances like vortices far behind an airplane. But such investigations are relatively easy in a long towing tank.

Also it should be said that this writer feels that the scope of the meeting should have been broadened somewhat to cover all Newtonian liquids, not just water. At times, in the fluid mechanics field, some very small detail of a flow must be investigated. The Reynolds number for this detail may be quite low. If a fluid having a higher viscosity than water is chosen for the test the size of the detail can be magnified easily a hundredfold. Another advantage is that certain viscous fluids have the property of photoviscosity, that is, by shining polarized light through a two dimensional flow, shear stress in the flow can be determined. Finally, it should be mentioned that cavitation bubbles or air bubbles under the right circumstances can be generated on a model in a water facility. Noting the formation of cavitation is a convenient way of observing that some local velocity has reached a certain C_p value, so to some extent pressure testing can be done without building in static tubes. Air bubbles on a model form a constant pressure surface that can indicate solutions to a fairing problem. The Germans in WWII used this method in some of their fighter development, but no mention of the cavitation or air bubble technique was made in this meeting.

I felt that the parts of the meeting concerning facilities and techniques were more positive than those concerning research results. This judgment is entirely subjective but my reason is that the papers on techniques seemed to describe developments that seemed more nearly finished than those described under Research Results. It seemed to me that many of the facilities described were well established, so that descriptions of them were timely. Many of the techniques seemed fully developed and only needed to be adapted to other facilities to go into general use. But research results mostly were in the nature of progress reports and more work on the different subjects was clearly needed.

Very good progress was indicated in the meeting in making the flow visualization aspects quantitative[14-23]. In earlier days the state of the art was to measure the length of a trace of an aluminum powder particle under a timed camera exposure to get an idea of the local velocity in a two-dimensional flow. Now direct LDV measurements are rather common and remarkable progress has been made on genuine measurement of true three-dimensional flow fields using holography, photogrammetry, double imaging and advanced computing and data reduction techniques. The methods are extremely sophisticated compared with those of the older days. All sorts of ingenious ideas were introduced and developed.

Because the results of observations are often quantitative, general results frequently can now be found that will give guidance to future work. But often the observations are so specific and detailed that no significant generalities can be deduced from them. But these detailed observations can be quite applicable to specific engineering problems. Hence modern flow visualization techniques are helpful in both general research and in specific engineering projects. The tremendous amount of detail that can now be gained is changing our approach to the study of flow details. It also is bringing on a problem - data handling and presentation. Mechanization must be developed. Then in order to make something of the data it must be presented in graphical fashion. Many of the papers bring this problem to our attention, e.g. refs. 15-23. I hope that the greater detail gradually leads to greater understanding of the flow processes. I am confident it will in time, because that has been the history of science. Once we are able to see more detail or make a refined measurement, some improvement in theory comes about. Nevertheless it is a real worry that for substantial periods of time all that this really increased detail of a flow will do is swamp us with more data, which will not be understood. But I am an optimist.

I will not make any comments on the specific papers. I have found that too dangerous. One paper that appears of no interest from a reviewer's standpoint may contain just what somebody else is looking for and vice-versa. But this evaluator will say that the several papers on quantitative and three-dimensional measurement struck him as especially interesting because they truly mark significant advances in this field[15-23].

I will pass on one word of caution about future meetings of this type. It is generally not enough just to give a paper that only shows a collection of spectacular flows. There should be some basic scientific advance in addition, or at least promised. Of course it is quite impossible to make any hard and fast statement. Werle's pictures[14] are outstanding mostly for their pictorial quality but they certainly qualify for a meeting of this sort because they have led the way. But I repeat, flow visualization is mainly a means to the goal of better understanding a flow, not an end in itself.

I came to this meeting wondering if certain variations in techniques would be covered to some extent. Most were. One was the use of hot water to get higher Reynolds number. It was mentioned and in fact used to a small extent. Another was stratification. It too was mentioned and its possibilities were briefly pointed out in connection with towing tanks. Although it does not qualify under the title of the meeting the use of liquids other than water is a possibility as already noted. There are a number of liquids with high viscosity that can be used to magnify the scale for low Reynolds number tests. Moreover with polarized light some

can indicate shear stress[43]. I believe Professor Hornung made a remark that it was too bad that some of the motion does not show up in color. In certain fluids that almost happens. Finally I wondered if any use of the air bubble technique of working out fairings such as the Germans did in WW II would be mentioned. It was not. Determining the shape of a three-dimensional bubble through the glass walls of a water tunnel is a complicated technique and requires use of methods like those described by Bippes in his paper[15]. Also of course the glass walls must be large in order to see the model adequately, and even then wings, etc. can obstruct the view.

This writer briefly investigated an alternate approximate but general technique that was applied to a nacelle model under the wing of an A3D airplane. The nacelle was represented by a straight tube having a short round front end to represent the leading edge of the inlet (Figure 1). Correct engine air flow was represented by water flowing through the tube. Air was introduced around the outside of the tube to form a bubble that would represent a constant velocity fairing in the presence of the wing. The problem then was to find the shape of the bubble, which was greatly hidden by the wing. The tube was about 2 cm in diameter and about 23 cm long. This tube was converted into a porcupine-like device as shown. A hundred or so tiny steel spines were soldered to the tube. They were lenticular in shape, about 0.1 mm thick and about 2 mm chord, aligned approximately with the flow, and long enough to reach through the bubble. They were small enough to have negligible effect on the shape of the bubble. Before testing, the entire assembly was flash copper plated. Then during a run, after air pressure in the bubble was set correctly and everything was stabilized, the model was flash unplated for a second or two. The part of the spine sticking through the bubble into the water would lose its copper and turn black, clearly marking the edge of the bubble. I had completely forgotten about these tests but Taras Kiceniuk of Caltech reminded me of them. He had operated the water tunnel when the tests were made about 1952. The technique was entirely successful but was not exploited because the project for which it was developed was dropped. Of course modern methods of inverse potential-flow calculation may be making techniques like these obsolete. So many of the flows observed and reported featured vortices in various environments, particularly in Refs. 1-5, that Professor A. D. Young commented that an alternate name for the meeting could have been VORTICAL FLOWS. This is quite true. Flows with vorticity are the ones that become very complicated and need the latest techniques of flow observation to learn what they really are like. In fact if these flows did not indeed have vorticity they would just be potential flows and then in time everything could probably be calculated.

This completes my report. I close by saying again that for many problems flow visualization is needed and the use of water is often the best medium to use. Of course there are many other applications of water besides flow visualization but water and flow visualization seem to go together. Perhaps I have given undue emphasis to this aspect but it seems to be the major distinguishing feature from air testing. Also I perceive that the use of water for both aerodynamic and hydrodynamic testing is gradually gaining wider acceptance. Meetings like this support this belief with respect to water and Ref. 36 supports it with respect to the flow visualization aspect in air. This symposium helps answer the need for bringing both the information on this subject and the workers together and was very good. Another one should be held, say in five years.

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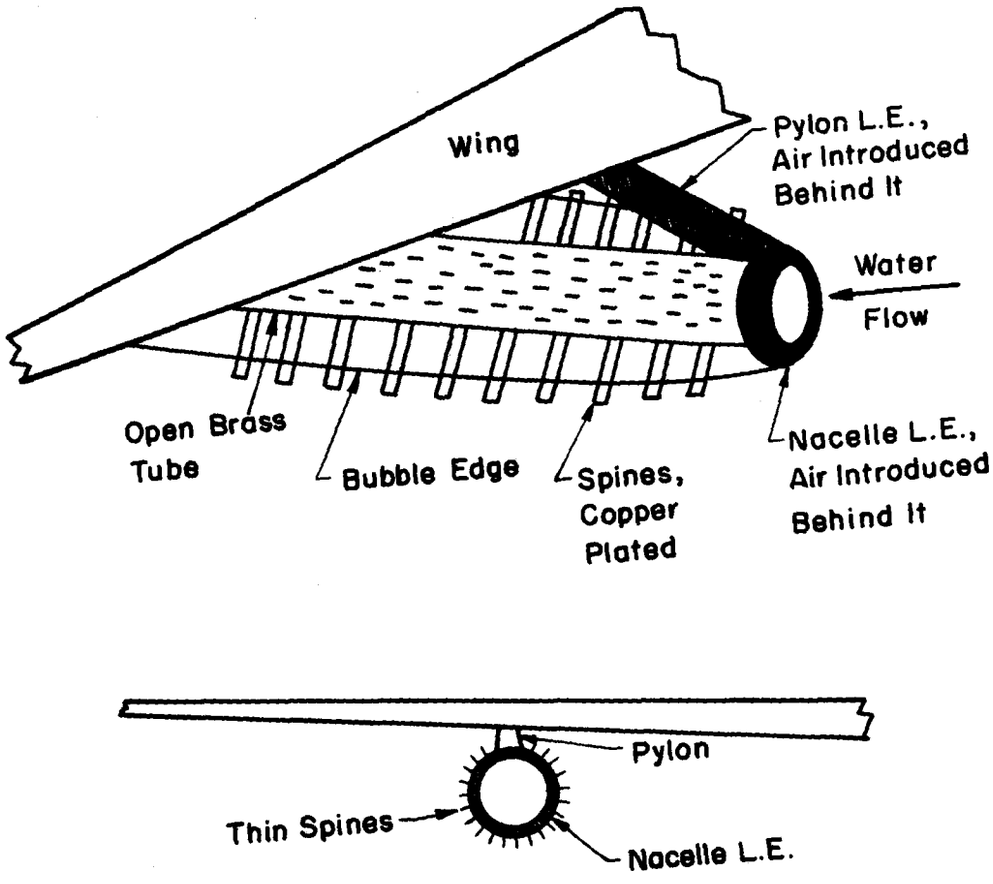

Schematic Of A Method For Determining A Cavitation Bubble Shape

Figure 1

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14. Abstract

This Fluid Dynamics Panel of AGARD conducted a Symposium to review and examine the results of aerodynamic investigations carried out in water facilities. These facilities include water tunnels, towing channels and stationary tanks. The author of this Technical Evaluation Report observes that the use of water as a medium for both aerodynamic and hydrodynamic testing is gradually gaining wider acceptance. This meeting allowed the specialists to gather and discuss their results, compare techniques and find solutions to problems. Another Symposium of this type would be timely several years in the future.

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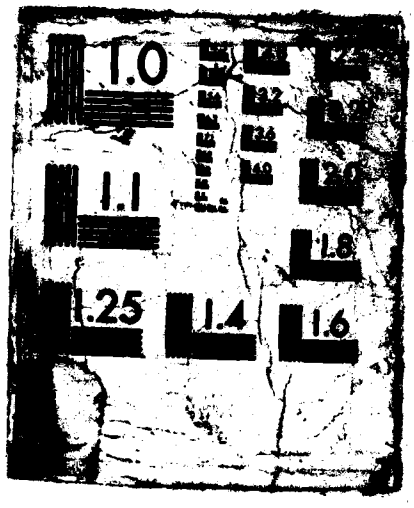
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The Author regrets the occurrence of a significant error in this publication.

The error appears on page 2, paragraph 4, line 6:

1/6 should read 1/16

Please make this change in the text. Thank you for your assistance.

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